European Case Studies of Anaerobic Digestion Plants Showcasing their Monitoring Practices

BIO-METHANE REGIONS

Promotion of bio-methane and its market development through local and regional partnerships

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THE AD CENTRE – THE WALES CENTRE OF EXCELLENCE FOR ANAEROBIC DIGESTION

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Introduction

Anaerobic Digestion (AD) is a complex biochemical process that takes place in sealed vessels, in which organic material is converted to a methane rich biogas that can be used to produce renewable electricity, heat or utilised as a vehicle fuel. A digestate is also produced that can contain valuable nutrients. The complex food chain that occurs within the AD process includes the processes of hydrolysis, acidogenesis, acetigenesis and methanogenesis, which are conducted by a consortia of microorganisms that require specific 'working conditions'. Within the microbial consortia the methanogens the, microbes that produce the methane, are quite sensitive to environmental conditions within the digester.

Considerations about the required working conditions must take place at design stage of AD Plants, where types of substrates, potential substrate pretreatments, loading rates, types of digestion systems, and possible further digestate and biogas processing among others would need to have been appropriately defined. Considerations however need to continue during start-up phase, during normal operation and during any shut-down periods. It is very common for an AD plant to modify (slightly) operations either by increasing loading rates or for example by taking different feedstocks that the plant was initially designed for and these change are likely to have impact on the efficiency of the AD process.

This report focuses on providing general information related to key parameters worth monitoring and controlling during the operation of an AD plant in order to:

- allow a certain flexibility of varying hydraulic and organic loading of substrates
- allow a slight diversification of types of substrates input
- treat wastes to a high degree (if substrates are classed as wastes)
- maximise organic conversion efficiencies to biogas/biomethane
- yield good quality digestates and biomethane
- reduce amount of plant/process downtime
- enhance environmental benefits of the plant and reduce any impacts
- enhance health and safety regime at the plant

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Ultimately, these benefits will have positive impacts on the economics of AD plants and will continue to add to the credentials of AD and biogas technologies. It is important that AD is considered a technology that delivers technically on a long term basis, that allows some operation flexibility, that it is a good neighbour, and that it delivers benefits in environmental and economic terms. It is also important that it delivers on promises made to government and the public in general. This will also help new proposals for AD systems gain faster acceptability by the public and planning officers and gain further, or continue to receive, support from government policies and financial incentives.

If AD plants do not monitor at least key parameters it is very difficult to achieve those aims listed above. It is similar to 'driving a car without a windscreen or a steering wheel'. It becomes difficult to benchmark operation and to optimise and enhance the plant's delivery. It is also difficult to understand what are the main contributing factors if there is a major process breakdown, which consequently limits the ability of providing fast remedial action. In cases where plants are not monitored and controlled effectively, reactor performance is likely to be sub-optimal and, as a worst case the biochemistry within a digester can fail. Re-innoculating and start-up phases can delay operation for many months. For example, if an acceptable conversion of the organic materials to biogas is not achieved, then in addition to reduced generation of energy, there will also be an increase in potential methane losses to the environment, which should be avoided at all cost. It is therefore imperative that a good understanding of the status of the process exists at an operation level.

Anaerobic Digestion is a complex biochemical process. In the case of a commercial biogas/biomethane production a stable process is a prerequisite to an economical and safe operation of an AD plant.

In order to ensure a stable process, operators will have to pay attention to various areas:

> *The AD Plant Equipment: State of the equipment and machinery implemented. Regular maintenance work and inspection of the plant's hardware is essential for a safe and successful operation.*
>
> *Training: Operators should have undergone training according to their specific duties at the plant. The plant's full potential can only be reached if personnel are adequately trained and instructed. Therefore regular training programmes are important.*
>
> *Monitoring: Monitoring of the AD plant's basic parameters should be in place. A good monitoring practice gives operators a picture of what is happening in the AD Process. Monitoring specific parameters in regular intervals allows for trends to be deduced and gives operators a chance to identify critical situation in advance. Leaving time to take precautionary measures is key to long term successful operation.*

Some plants may require more careful monitoring than others, for example when a plant operates a high loading rate or a low retention time, or if a number of substrates are being co-digested and their

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quantity and quality continually changes. It is understood that monitoring of the various parameters is not necessarily always done on-line due to, in some cases, lack of reliable intrumentation and the costs involved. Also, due to costs limitations, some plants may only measure parameters during start-up phases and when significant changes in operation occur. Some of the parameter monitoring may also only be performed off-line and samples will be sent to external laboratories for analysis and therefore delays in receiving results will occur.

However, it is important to have in mind that the more parameters that are monitored, the greater handle of process conditions and the greater flexibility to control operation. **There is never too much information, and the faster the information becomes available the quicker a control action can take place! And with living microorganisms performing the essential tasks, time is of the essence.** It is also important that the data is analysed and understood and therefore operator's knowledge and experience cannot be overlooked.

This publication intends to also demonstrate monitoring practices throughout Europe that have led to stable operation of full scale AD plants. Experts from the Universitity of Glamorgan, the Technical University of Vienna and AD Plant experts have collected and selected a number of case studies detailing monitoring practices from across Europe. It is possible that other case studies will be added to this document during the development of this project.

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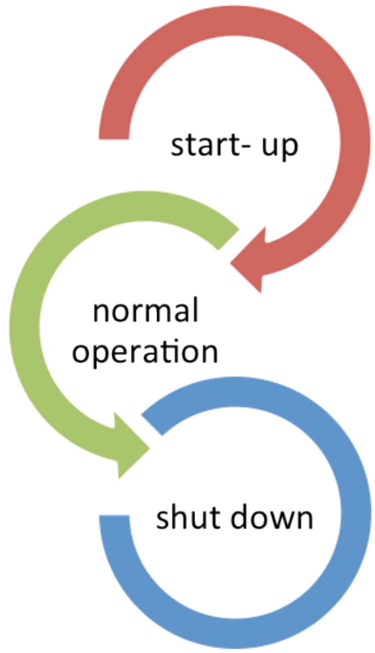
Anaerobic Digestion Plant Monitoring

Key Monitoring and Control Schemes

With increasing know-how of AD plant operators – the optimization of plants plays a major role in today's AD Plant operation. In order to operate an AD Plant safely it is necessary to record, control and analyse various plant parameters.



An AD plant's process control can be separated into three phases: 1) Start-up, 2) normal operation which will include 'almost steady state' as well as more transient operating conditions, 3) shut down.

Each phase of the operation has special requirements with regard to the monitoring and control schemes that need to be implemented. Health and Safety related parameters and procedures may differ during the three phases, but information on this is not the emphasis of this report.

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Key Parameters

This chapter is a brief excerpt from the *Monitoring Guide* published by the Bio-Methane Regions project team, which explains the importance and impact of these parameters, value ranges and analytical techniques and instrumentation normally used to perform the monitoring task.

There are numerous parameters that can be monitored (view – AD-plant parameter study available on http://www.bio-methaneregions.eu/). The following diagram indicates the different types of parameters according to the phase of the AD-process:

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The combination of a number of the above parameters will provide a good understanding of the operation of the plant. In addition, AD plants are also normally described by a series of other parameters and they have been listed below. These are more general than the parameters listed above, but describe typical operation and include annual production and utilisation of energy. This information is normally used to summarise the AD plant profile and allows benchmarking between processes and plants to take place as well as to map out AD capacity in regions. These figures are normally compiled at design stage and based on projected performance but can be revised if operation and data has changed. These revisions are compiled based on the operator's documentation. The information typically provides a general overview of the typology of AD-plants. The typology in this case refers to the feedstocks/substrates used and annual throughput, type of digester used, data that relates to energy production and consumption as well as the quanity and fate of digestates. Usually no specific costs are incurred when compiling these figures. The compilation and logging of these data is part of general good practice and in many cases are required by national environmental regulations as well as through returns on renewable energy that has been incetivised through government schemes.

- Annual/Daily quantity and type of of substrate
- Type of digestion system
- CH_4 yield per tonne of substrate (wet or dry basis)
- Annual/Daily biogas/biomethane production
- Annual/Daily electricity production
- Annual/Daily parasitic electricity load
- Annual/Daily heat production
- Annual/Daily parasitic heat load
- Output and markets for digestate
- Addional fuel/energy requirements

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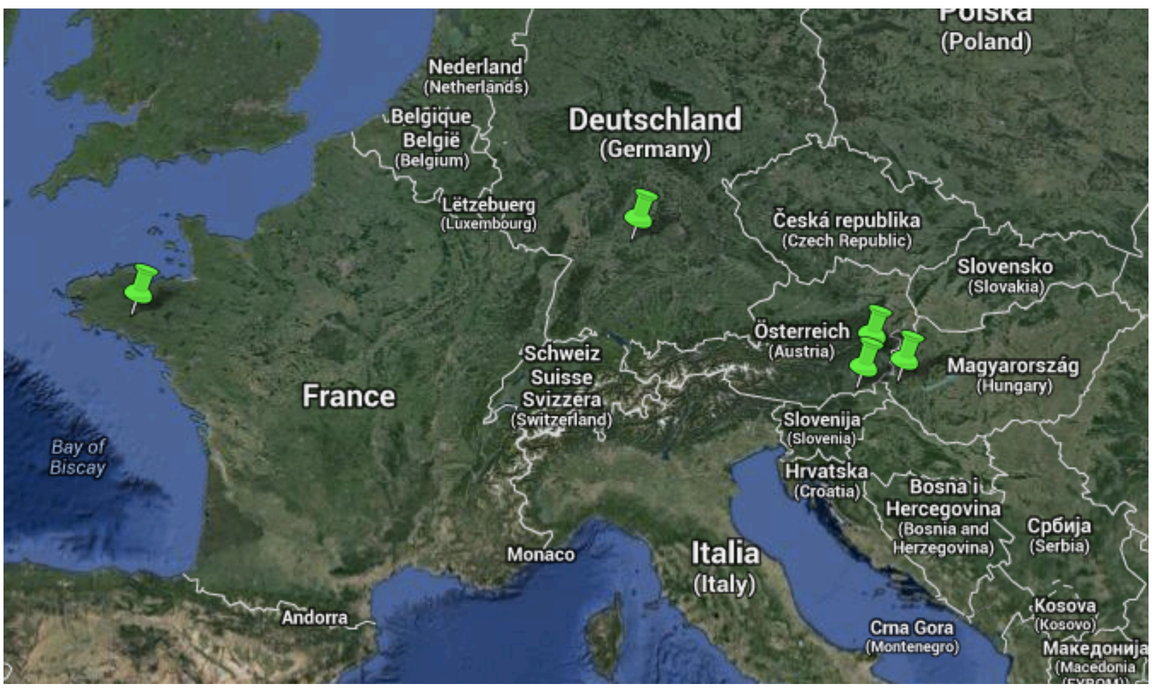
European Case studies of AD Plants and Their Monitoring Regimes

The following case studies feature monitoring practices in AD plants throughout Europe (view map below). Partners from the Bio-Methane Regions project have collected data of existing AD Plants in the partner countries. The collected cases have been analysed, selected and compiled by experts from the University of Glamorgan (Wales), Technical University of Vienna (Austria) and the Styrian Energy Agency (Austria).



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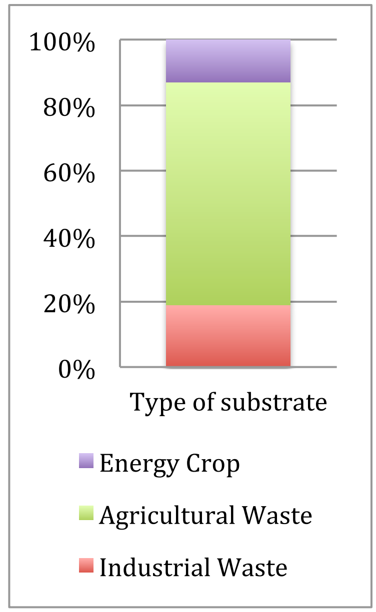
Biogas plant Mureck (Austria)

Plant Type:	**Biogas plant with CHP**
Substrates:	industrial, liquid manure, agricultural wastes and maize
Total Input:	23,000 t/a
Annual Output:	2,100,000 Nm^3 CH_4 & 8,390 MWh_{el} & 6,500 MWh_{th}
Power rating el. :	999 kW_{el} (CHP)
Commissioned:	2005
Plant Costs:	€ 5,400,000

General AD Plant description AD plant Mureck

In 2001, the idea to realize an AD plant beside an existing biodiesel production and biomass district heating system, was born. The AD plant comprises of a mixing tank (300m³) a ligavator-system (LIPP-Ligavator, 4x 1,000m³), four digesters (4x 1,000m³) and the storage for the digestate. In the mixing tank maize, corn cob mix (CCM) and liquid manure is mixed and pumped into the LIPP-Ligavators. From the Ligavators the feedstock is pumped to the four digesters. The AD plant forms part of a wider system of bioenergy production including biodiesel production (12 Mio litre), a biomass district heating system (4 MW), the AD plant and a photovoltaic plant (1 MW_p).



Monitored Parameters at AD Mureck

The following table shows the parameters that are being monitored.

Monitoring Parameters			
Parameter	**Frequency**	**Method**	**Location**
Feedstock parameters that are being monitored			
VS & TS content	Upon arrival	Off-line	On site
Digester parameters that are being monitored			
Temperature	Continuous	Online	On site
pH	Weekly	Off-line	On site
Biogas parameters that are being monitored			
H_2S	Continuous	Online	On site
Biogas yield	Daily	Online	On site
O_2	Daily	Online	On site
Digestate parameters that are being monitored			
Nutrients & trace elements	4 time a year	Off-line	Laboratory
Heavy metals	Yearly	Off-line	Laboratory
N/kg digestate, N total	4 times a year	Off-line	Laboratory
VS & TS content	4 times a year	Off-line	Laboratory
pH	4 times a year	Off-line	Laboratory
Salmonella	4 times a year	Off-line	Laboratory

Outcomes of monitoring in Mureck

The monitoring arrangement shows a basic monitoring set up. Great importance is given to the monitoring of the biogas. An automatic control panel has been installed to facilitate operators with gaining data on the biogas parameters. The average downtime of 360 hours per year is primarily due to maintenance works. Another area of specific interest is the digestate quality. In this case the digestate is used as fertilizer and therefore requires analysis before it is brought out on to the fields.

Specific Costs of Monitoring: AD Plant Mureck	
av. external monitoring costs/ a (lab, consultancy spending):	€ 3000.-/a
av. internal monitoring costs:	7 h/week
av. training costs:	€ 1500.-/pp every 5 years
investment costs for on-site monitoring/analysis equipment:	€ 50000.-

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Waste Water Treatment Plant Zalaegerszeg (Hungary)

Plant Type:	**Biomethane filling station from Waste Water**
Substrates:	Sewage sludge
Total Input:	50,000 – 60,000 t/a (5% dry matter content)
Annual Output:	1.1.1.1 370,000 m^3 Biogas 580 MWh_{el}
Commissioned:	2011
Plant Costs:	€ 600,000 - €700,000

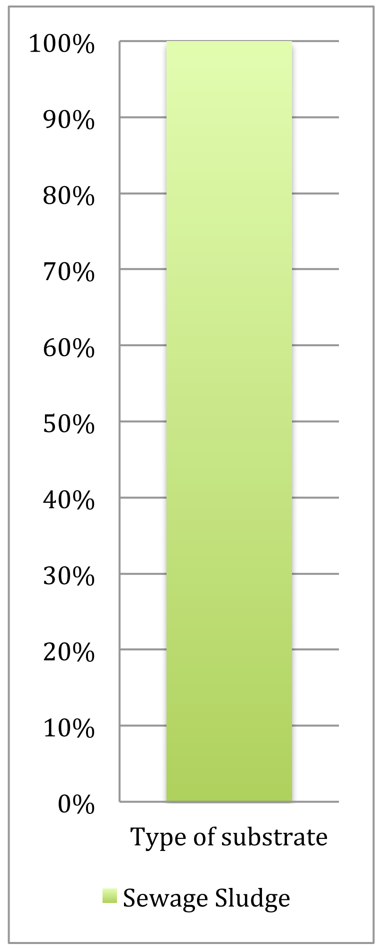
General AD Plant description of WWTP Zalaegerszeg

The Zalaegerszeg Wastewater Treatment Plant uses surplus or waste activated sludge as a feedstock. The digester was installed because of the requirement to treat the sludge prior to disposal and the plant was constructed with the support of the EU.

The two mesophilic digesters are equipped with top stirrers and their total volume is 2.920 m^3 (1.460 m^3/each). The wastewater treatment plant does not have a primary clarification tank, therefore only the secondary sludge is used in the digestion process. The average daily biogas production is 1.000-1.200 m^3 / d which can be used in three ways:

- Electricity
- Heat
- Vehicle Fuel

Biogas is upgraded for vehicle fuel in 2 steps: activated carbon absorber is used to remove hydrogen sulfide (H_2S) and a water scrubber is used to remove carbon dioxide (CO_2) from the raw biogas. Upgraded gas is then available for compression (to around 200 bars) for storage in buffer storage. The buffer storage is necessary to allow the (fast charge) filling.



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Monitored parameters at Zalaegerszeg Waste Water Treatment Plant

The AD plant in Zalaegerszeg has a total of 26 sampling ports to conduct off-line sampling for laboratory and on site analysis of gas and materials. The following table shows the key parameters that are monitored on a regular basis. The system is run automatically and a daily monitoring routine is conducted by AD-Plant personnel.

Monitoring Parameters			
Parameter	Frequency	Sampling	Location
Feedstock parameters that are being Monitored			
VS & TS content	2 times a week	Off-line	On site
Digester parameters that are being monitored			
Temperature	Continuous	Online	On site
Organic loading rate	Weekly	Off-line	Laboratory
TS	Weekly	Off-line	Laboratory
pH	Continuous	Online	On site
VFAs	Weekly	Off-line	Laboratory
Biogas parameters that are being monitored			
Gas flow rate	Continuous	Online	On site
Biogas yield	Daily	Online	On site
Digestate parameters that are being monitored			
Nutrients & trace elements	3 times a year	Off-line	Laboratory
N/kg digestate, N total	Weekly	Off-line	Laboratory
VFAs	2 times a week	Off-line	Laboratory

Outcomes of monitoring in Zalaegerszeg Waste Water Treatment Plant

Since starting operation in 2010, Zalaegerszeg plant operators have found monitoring practices to be vital in circumstances when immediate intervention was required. A webscada system is in place to alert if any of the online parameters show significant deviations from the norm. Downtimes have been kept low, limited to the biannual maintenance works that are being conducted.

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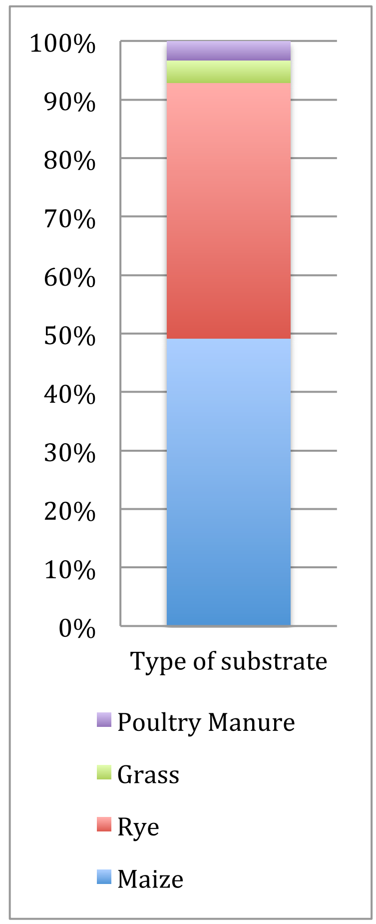
Biomethane Plant Emmertsbühl (Germany)

Plant Type:	**Biomethane Plant w. grid injection**
Substrates:	Maize, Rye, Grass, Poultry manure
Total Input:	Approx. 18,000 t/a (9,5% TS - content)
Output:	400- 450 Nm^3 Biogas/ h 53,2% CH_4 255 Nm^3 Bio-Methane/h
Commissioned:	2005

General AD Plant description of AD Plant Emmertsbühl

A new concept has been in use since 2010 by the Biomethane Plant Emmertsbühl (Schwäbisch-Hall, Germany). The Bio-Methane produced at the plant is injected into the low-pressure gas grid as opposed to the conventional high-pressure transport gas grid. A basic requirement for this to work is that the local gas demand is as high as the production of the Biomethane plant in Emmertsbühl. In local gas grids this is not always the case. Usually gas is first compressed and then injected into the high pressure transport gas grid. In Emmertsbühl only the excess Biomethane is pressurized and then injected into this high pressure grid. This concept saves costs and energy. EnBW, the owner of the upgrading facility has patented this method.



The AD Plant has two process lines. Each has a main digester (1600 m^3 & 2000 m^3) and a post fermenter. The digestate of both of the lines are stored in a sealed tank.

The Biogas Plant is owned by a farmer. The upgrading and injection facility is owned by the regional energy company EnBW.

Monitored parameters in Emmertsbühl

The monitoring of the plant is divided into two sections. The monitoring activities for the biogas production is conducted by the plant owner and operator. Since the operation of the upgrading and injection facility is owned by a regional energy company (EnBW), the monitoring is conducted on site via telecommunication technology by EnBW.

Monitoring Parameters

Parameter	Frequency	Sampling	Location
Feedstock parameters that are being Monitored			
VS & TS content	Monthly	Off-line	Laboratory
Potential biogas yield	Monthly	Off-line	Laboratory

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pH, alkalinity	Monthly	Off-line	Laboratory
C:N:P:S analysis	Monthly	Off-line	Laboratory
	Digester parameters that are being monitored		
Temperature	Continuous	Online	On site
Organic loading rate	Monthly	Off-line	Laboratory
TS	Monthly	Off-line	Laboratory
pH	Continuous	Online	On site
Hydraulic and solid retention times	Monthly	-	-
VFAs	Monthly	Off-line	Laboratory
	Biogas parameters that are being monitored		
Gas flow rate	Continuous	Online	On site / telemetry
CH_4, CO_2, H_2 partial pressure	Continuous	Online	On site / telemetry
H_2S, NH_3, trace gases, impurities	Continuous	Online	On site / telemetry
	Digestate parameters that are being monitored		
Nutrients & trace elements	3 time a year	Off-line	Laboratory
N/kg digestate, N total	3 times a year	Off-line	Laboratory
TS and VS	3 times a year	Off-line	Laboratory
VFAs	3 times a year	Off-line	Laboratory
pH	3 times a year	Off-line	Laboratory

Outcomes of monitoring in Emmertbühl

The AD-plant in Emmertsbühl has an astounding record of 8760 h/a operating time since it started injecting into the grid. Prior to the AD-plant at Emmertbühl being equipped with upgrading equipment it ran two CHPs. Even then the plant managed to produce electricity on 8660 h of the year in average with 80 hours / a dedicated to maintenance works on the gas engines. Only 20 hours down time per year were due to unforeseen repairs. When asked what paramerters are most important to monitor, the owner replied the biogas quality. Running an AD-plant without recording and analyzing the biogas quality would be like "driving a car without a license".

Specific Costs of Monitoring: AD Plant Emmertsbühl	
av. external monitoring costs/ a (lab, consultancy spending):	€ 8000.-/a
av. internal monitoring costs:	€ 9125.-/a
av. training costs:	€ 1000.-/a
investment costs for on-site monitoring/analysis equipment:	€ 400 - € 500 rented from EnBW

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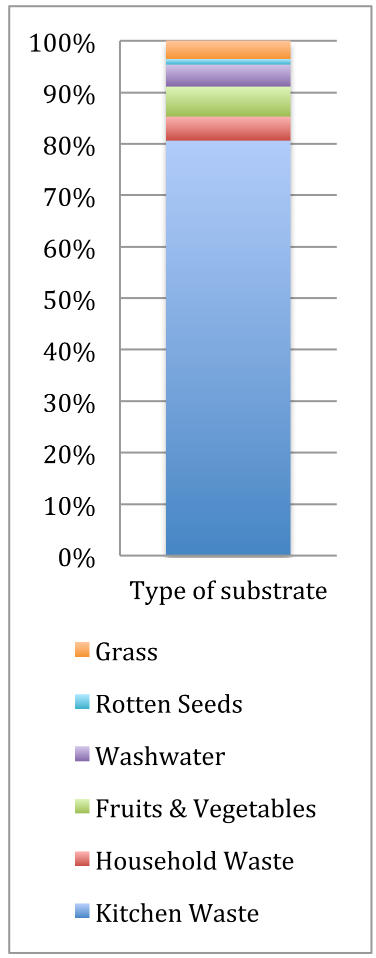
AD Plant Hartberg (Austria)

Plant Type:	Biogas Plant + 2 x CHP
Substrates:	Kitchen wastes, household waste, fruits & vegetables, washwater, rotten seeds, filter cake residues, gras
Total Input:	Approx. 6,000 t/a (approx. 6% TS - content)
Output:	110 Nm^3 Biogas/ h 60% – 65% CH_4
Power rating elect:	$100kw_{el}$ + $180kw_{el}$
Commissioned:	2004
Plant Costs:	€2,100,000

General AD Plant description of AD Plant Hartberg

The AD of Biokraft Hartberg at the location “Eco park Hartberg” is one of two “twin AD plants” of Biokraft Hartberg. The sister AD is located in the village of Habersdorf at a waster water treatment plant about 4 km from the loction of Eco park Hartberg.
All the feedstock is pre treated (shredding, sorting and pasteurization) at Habersdorf and deliverd by truck to eco park Hartberg.

The AD of Eco park Hartberg comprises of 3 horizontal digesters (plug flow through), each 160m³.
After 20 days in the digester the feedstock is pumped to two post digesters (2x 1,000m³), then it is pumped to the storage. The storage for the digestate is also covered to collect residual biogas.
The utilization of the biogas is by two CHP´s at the energy center of Eco park Hartberg (about 300 meters from the AD). The produced electric energy is feed into the public grid. The thermal energy is used at the local district heating system of Eco park Hartberg in combination with a biomass boiler. The thermal energy is used for heating, warm water and cooling in summertime.



Monitored and parameters at AD Plant Hartberg

Each digester has a samping port. The following table shows the parameters that are being monitored with the corresponding frequencies. The operator requires approximately 1 hour a week to conduct this basic monitoring programme.

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Monitoring Parameters			
Parameter	**Frequency**	**Sampling**	**Location**
Digester parameters that are being monitored			
Temperature	Continuous	Online	On site
pH	Weekly (+every 6-8 weeks)	Off-line	On site (laboratory)
VFAs	every 6-8 weeks	Off-line	Laboratory
Biogas parameters that are being monitored			
Gas flow rate	2 times a week	Handheld measurement	On site
CH_4, CO_2, H_2 partial pressure	2 times a week	Off-line	On site
H_2S, NH_3, trace gases, impurities	2 times a week	Handheld measurement	On site
Digestate parameters that are being monitored			
Nutrients & trace elements	2 times per year	Off-line	Laboratory
N/kg digestate, N total	2 times per year	Off-line	Laboratory
TS & VS	2 times per year	Off-line	Laboratory
Potential residual methane/biogas	2 times per year	Off-line	Laboratory
Salmonella, enterobact.	2 times per year	Off-line	Laboratory

Outcomes of monitoring in AD Plant Hartberg

When asked as to what is one key factor when monitoring, the operator answered that one of the major challenges is to get a representative sample of the digestate or substrate . If the material's properties do not in anyway match the recovered sample then analytic results generate a false impression of what is going on in the AD process, which may then lead to incorrect decisions being made and an unstable AD process. In this particular case, when an AD plant is run on a variety of feedstocks with varying quality, the operator's experience with handling different feedstocks is vital. Due to the lack of funds the operator does not have an automatic control/monitoring unit installed. When asked what he would like to be able to measure, he replied that an online gas-content would be his preferred parameter.

"At the beginning we had a lot of troubles with the AD equipment, the supplier and the feedstock mixture. A long period (several years) experience is essential to improve the output of the AD, in the very first beginning a detailed monitoring scheme is useful but very costly. It requires a lot of time to get the optimum feedstock mixture. Now we have optimised it and have reduced the troubles in the AD plant to a very low level."

Specific Costs of Monitoring: AD Plant Hartberg	
av. external monitoring costs/ a (lab, consultancy spending):	€ 5000.-/a
av. internal monitoring costs:	1 h/week
av. training costs:	-
investment costs for on-site monitoring/analysis equipment:	€ 25000.-

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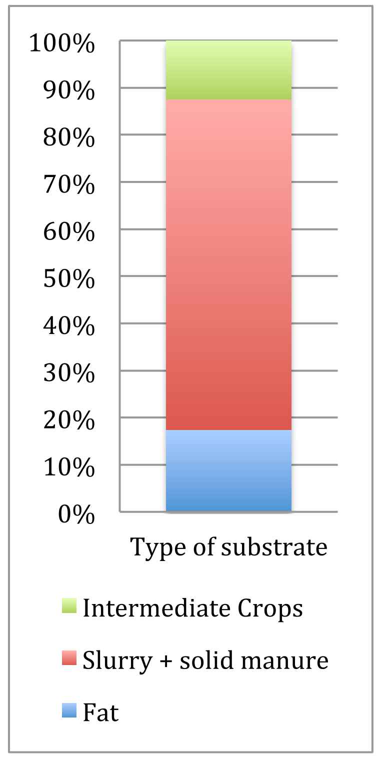
AD Plant in Moustoir-Remungol (France)

Plant Type:	AD Plant + CHP
Substrates:	Fat, slurry & solid manure, intermediate crops
Total Input:	Approx. 7,200 t/a
Annual Output:	385,000 Nm^3 Biogas 60% - 62% CH_4 content 223,000 Nm^3 Bio-Methane
Power rating elect:	$110kW_{el}$
Commissioned:	2010
Plant Costs:	€750,000.-



General AD Plant description of AD plant in Moustoir-Remungol

The operator's main reason to build the AD plant, was to make his farm energy autonomous. In February 2010, the AD plant was first started up with pig slurry. As of March 2010 the gas engine for the CHP had reached its optimal power rating of 110 kW_{el}. The AD plant runs on fat, manure, slurry and intermediate crops.

Liquid feedstock such as fat have a reception tank (80 m^3). Solid materials are added via a silo (600 m^3). A smaller tank for daily supply of slurry is installed. The digester has a capacity of 1200 m^3 followed by the wet system post-digester with 730 m^3 that additionally acts as a digestate storage. The main digestate storage is limited to 340 m^3 in the post digester. The digestate is redistributed as a fertilizer on the fields.

Monitored parameters at AD plant in Moustoir-Remungol

The AD Plant in Moustoir-Remungol has an online monitoring system. Parameters such as temperature, pH, gasflow -rate, trace gases and impurities are recorded. In addition to the monitoring system the plant operator is warned via a Téléalarm-System when critical operating conditions are recorded.

Monitoring Parameters

Parameter	Frequency	Sampling	Location
Feedstock parameters that are being monitored			
TS & VS	At reception	Off-line	
Carbs, lipids, proteins, heavy metals, light metal ions	Every two years	Off-line	Laboratory
Anticipated biogas yield / feedstock	At reception	Off-line	Laboratory
pH and alkalinity	1 to 2 times a year	Off-line	Laboratory

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C:N:P:S analysis	1 to 2 times a year	Off-line	Laboratory
Digester parameters that are being monitored			
Temperature	Continuous	Online	On site
Organic loading rate	Every 4 months	Calculated	calculated
pH	Continuous	Online	On site
C:N:P:S ratio	Every 4 months	Off-line	Laboratory
VFAs	Every 4 months	Off-line	Laboratory
Biogas parameters that are being monitored			
Gas flow rate	Continuous	Online	On site
CH_4, CO_2, H_2 partial pressure	Continuous every 10 min before CHP + hand-held twice a day	Off-line + Online	On site
H_2S, NH_3, other trace gases & impurities	Continuous	Online & hand-held measurement	On site
Biogas yield	Continuous	Online	On site
Digestate parameters that are being monitored			
Nutrients & trace elements	4 times per year nutrients, 1 times a year trace elements	Off-line	Laboratory
N/kg digestate, N total	Before spreading	Off-line	Laboratory
TS & VS	4 times per year	Off-line	Laboratory
pH	Continuous	Online	On Site
Contaminants	1 time per year	Off-line	Laboratory
Nutrients and pathogen	1 time per year Salmonella, E.Coli, Helminths eggs	Off-line	Laboratory

Outcomes of monitoring AD plant in Moustoir-Remungol

This plant had an unscheduled (i.e. excluding maintainance) downtime of 130 hrs in the past 2 years which demonstrates the great effectiveness of appropriate monitoring regimes. Over 50 hours downtime were due to problems with the electric grid system whereas problems with the CHP caused a downtime of 24 hours. Approximately 50 hours where due to the AD process.

Specific Costs of Monitoring: AD Plant Moustoir-Reumungol	
av. external monitoring costs/ a (lab, consultancy spending):	€ 4700.- to €6100.-/a
av. internal monitoring costs:	€3000.- to €4000.-/a
av. training costs:	n.a.
investment costs for on-site monitoring/analysis equipment:	€ 52000.-

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Conclusions

An effective monitoring scheme is a prerequisite to maintaining AD process stability, plant safety and economic effiency.

The above examples have shown a variety of monitoring practices that are implemeted by European AD plant operators. The practices carried out by operators have been adapted according to the legal requirements (e.g. digestate monitoring so it can be used as fertilizer), technological requirements (e.g. Emmertsbühl where supply must equal demand of low pressureized bio-methane) and budgetary requirements (e.g. small scale farm AD plant). With this in mind, it comes to no surprise that the expenditures for monitoring (investment, internal and external costs, training) vary amongst the plants featured in this document. Amongst the common benefits of the implemented monitoring practices is the relatively high process stability of the featured plants. The added control over the process lets operators identify critical areas of the process in time and allows for plant-specific precautionary measures to be implemented. The operators identified regular and consistent monitoring practices as a must to achieve an economicaly sound and safe AD process

Online or web based monitoring systems are a vital asset in controlling the process in AD plants. In most of the case studies these systems are being used. Parameters such as digester temperature and pH, gas flow rate and biogas composition were monitored online. Only one out of the five plant operators did not have this system in place. This specific AD plant operator mentioned during the interview that an online monitoring system was on the top of his wish list.

What can be monitored is described in the BioMethane Regions project publication on monitoring parameters that is available on the Project website http://www.bio-methaneregions.eu/.

Although AD plants monitoring does not replace qualified personnel, the interviewed operators stressed its importance in every day AD plant operation as a contribution to site safety and increased plant profitability.

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